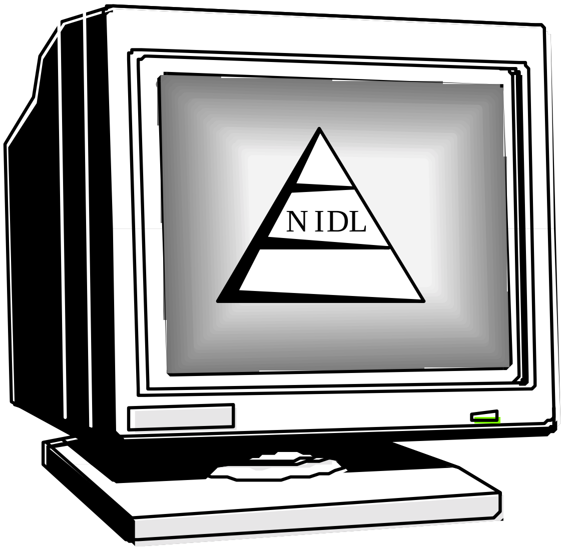

NIDL certifies the EIZO F980 color monitor as being suitable for IEC workstations. NIDL rates this color monitor as a "B" in both monoscopic and stereoscopic mode for the Image Analyst and Cartographer applications. EIZO's high maximum horizontal scanning frequency of 137 kHz allows it to easily meet the stringent 60 Hz per eye stereo refresh rate required for IEC monitors. The 1-pixel-on/1-pixel-off contrast modulation for the EIZO (37%) exceeds the IEC requirement (25%). It is about the same as NIDL measured for the Viewsonic P817 (29%), the Hitachi CM814 (35%), and for the Siemens SCM21130 (36%). The difference in contrast modulation for the EIZO compared to the "A" rated Cornerstone (57%) comes about because of the EIZO's lower vertical grill values. The horizontal grill values for the EIZO and the Cornerstone are roughly equal. The F980 features a shadow mask CRT (not a Trinitron) with a dot pitch of 0.23 mm (0.20 mm horizontal) and a phosphor-to-pixel ratio of 0.82. Their SuperErgoCoat reduces reflectivity to 4.4%. For comparison, the reflectivity of the Cornerstone p1700 NIDL-certified monitor is 5%, so the SuperErgoCoat seems to be effective. A lower reflectivity allows a higher dynamic range in a lighted room by maintaining a lower black luminance. EIZO also incorporates several circuits to assure accurate color reproduction, and to adjust up to 256 locations on the screen to eliminate convergence errors. NIDL paid $1790 for the EIZO F980 monitor.

Evaluation of the EIZO F980 4 x 3 Aspect Ratio, 21-Inch Diagonal Color Monitor

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CONTENTS

NIDL IEC Monitor Certification Report

The EIZO FlexScan F980 Color CRT Monitor

FINAL GRADES
Monoscopic Mode: B
Stereoscopic Mode: B

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way.

NIDL certifies the EIZO F980 color monitor as being suitable for IEC workstations. NIDL rates this color monitor as a “B” in both monoscopic and stereoscopic mode for the Image Analyst and Cartographer applications. The FlexScan F980 is EIZO’s most advanced CRT monitor to date, and has been designed for high-end graphics use. EIZO’s high maximum horizontal scanning frequency of 137 kHz allows it to easily meet the stringent 60 Hz per eye stereo refresh rate required for IEC monitors. The 1-pixel-on/1-pixel-off contrast modulation for the EIZO (37%) exceeds the IEC requirement (25%). It is about the same as NIDL measured for the Viewsonic P817 (29%), the Hitachi CM814 (35%), and for the Siemens SCM21130 (36%). The difference in contrast modulation for the EIZO compared to the “A” rated Cornerstone (57%) comes about because of the EIZO’s lower vertical grill values. The horizontal grill values for the EIZO and the Cornerstone are roughly equal.

The F980 features a shadow mask CRT (not a Trinitron) with a dot pitch of 0.23 mm (0.20 mm horizontal) and a phosphor to pixel ratio of 0.82. EIZO uses their SuperErgoCoat to reduce reflectivity to 4.4%. For comparison, the reflectivity of the Cornerstone p1700, NIDL-certified monitor is 5%, so the SuperErgoCoat seems to be effective. A lower reflectivity allows a higher dynamic range in a lighted room by maintaining a lower black luminance. EIZO also incorporates several circuits to assure accurate color reproduction, and to adjust up to 256 locations on the screen to eliminate convergence errors.

It can be noted that EIZO also features a 50 inch plasma display panel, and a 19.6 inch 1600 x 1200 pixel native resolution (0.249 x 0.249 mm pixel size) LCD color monitor in their lineup of high performance displays. Their website is www.eizo.com.

A comparison of the EIZO FlexScan F980 with other color CRT monitors is shown in the following table.

NIDL Color Monitor Certification for IEC

Monitor Manufacturer	IEC Spec	Cornerstone	EIZO	Viewsonic		Mitsubishi		Hitachi	SONY		Siemens
Model		P1700	F980	PF815	P817	2040U	2020U	CM814	24W900	F500	SCM21 130
Certified*		Y	Y	N	Y	N	N	Y	Y	N	Y
Monoscopic		A	B	A	B	A	C	B	A	B-	B
Stereoscopic		B	B	C	B	C	C	B		C	B
Cm, Zone A	25%	57%	37%	55%	29%	54%	30%	35%	64%	43%	36%
Cm, Zone B	20%	52%	27%	47%	40%	42%	16%	30%	53%	37%	21%
Refresh per eye	60 Hz	60 Hz	60 Hz	55 Hz	60 Hz	55 Hz	55 Hz	60 Hz	46 Hz	56 Hz	60.5 Hz
Extinction ratio, panel	No spec	10.6	12.6	10.3	10.1	10.4	11.1	11.2	12.9	13.3	11.2
IR glasses	15.1	21.0	14.3	17.6		17.6					18.1
Price		$1363	$1790	$926	$1600	$1123		$1200	$2371	$1758	< $2800

* Certified by NIDL requires achieving a rating of “B” or above for stereoscopic and for monoscopic performance relative to the IEC Working Group specifications listed in the Evaluation Datasheet. This summary is a compilation of ratings for color monitors from previously NIDL IEC monitor reports. The ratings for the Cornerstone, EIZO, and the Viewsonic PF815 are new.

Evaluation Datasheet

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1600 x 1200	Pass
Dynamic Range	24.7dB	25.1 dB	Pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.1 fL	Pass
Luminance (Lmax)	30 fL ± 4%	32.4 fL	Pass
Uniformity (Lmax)	20% max.	14.1%	Pass
Halation	3.5% max.	4.15 ± 0.4%	Fail
Color Temp	6500 to 9300 K	9110 K	Pass
Reflectance	Not specified	4.4%	N/A
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 delta u'v'	0.003 delta u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	9.65 H x 9.53 V (mils) H = V+ 1.2%	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	19.2 ins.	Pass
Cm, Zone A, 7.6"	25% min.	37%	Pass
Cm, Zone A, 9.5"	25% min.	35%	Pass
Cm, Zone B	20% min.	27%	Pass
Pixel density	72 ppi min.	104 ppi	Pass
Moiré, phosphor-to-pixel spacing	1.0 max	0.82	Pass
Straightness	0.5% max ± 0.05 mm	0.16%	Pass
Linearity	1.0% max± 0.05 mm	1.0% (72 Hz)*	Pass
Jitter	2 ± 2 mils max.	0.95 mils	Pass
Swim, Drift	5 ± 2 mils max.	1.99 mils	Pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	6 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	42 mins.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 85 Hz	Pass
STEREOSCOPIC			
Addressability	1024 x 1024 min.	1024 x 1024	Pass
Lmin	Not specified	0.1 fL	Pass
Lmax	6 fL min ± 4%	7.1 fL	Pass
Dynamic range	17.7 dB min	18.4 dB	Pass
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 delta u'v'	0.008 delta u'v'	Pass
Refresh rate	60 Hz per eye, min	60 Hz, per eye	Pass
Extinction Ratio with ZScreen	Not Specified	12.6:1 (z)	N/A
Extinction Ratio with CrystalEyes	15:1 min	14.3:1 (IR)	Fail
AMBIENT LIGHTING			
Dynamic range = 22.3 dB (170:1)	N/A	2 fc	
Dynamic range = 17.8 dB (60:1)	N/A	10 fc	

* 1.2% linearity at 85 Hz which exceeds 1.0% specified. Since it achieves 1% at 72 Hz, it passes.

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the EIZO F980 color CRT high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091***,** *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: Monochrome CRT Monitor Performance Draft Version 2.0. (ADA353605)*

- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1 The EIZO F980 Color CRT Monitor

Manufacturer's Specifications

According to EIZO NANAO Corporation, the specifications for the EIZO F980 monitor are:

Specifications	**Features**
CRT Type	21 inch class, 90° deflection Invar Shadow Mask (19.7" diagonal viewable area) 90 degree deflection
CRT Phosphor Pitch	0.23 mm / 0.20 mm (Horizontal)
CRT Faceplate Glass	SuperErgoCoat®
CRT Phosphor	
Display Area Size* (W x H)	15.8 x 11.8" (402 mm x 300 mm)
Addressable Format (H x V pixels)	2048 x 1536 at 85Hz, maximum 1600 × 1200 at 109 Hz, recommended
Input Signal Sync: Video:	RGB Analog H/V Separate, TTL, Positive/Negative H/V Composite, TTL, Positive/Negative Sync-on-Green at 0.3 Vp-p, Negative Analog 0.7 Vp-p/75 ohm, Positive
Plug and Play	VESA DDC 1/2B
Scanning Frequency (Automatic)	H: 30 - 137 kHz V: 50 - 160 Hz
Pixel Clock Frequency	400 MHz
Fully Adjustable Color	4000°K to 1000°K (9300°K default) with automatic correction
Compatibility	PC and Mac with optional adapter
Connectors	Video: D-sub 13W3, BNC x 5 [RGBHV] Power: 3-pin plug
USB Ports	1 Upstream port (for computer or another hub) 4 Downstream ports (for peripherals)
Signal Cable	D-Sub 13W3 pin to D-Sub mini 15 pin
Cable Accessories	Macintosh adapter not included.
Power Requirements	100-120VAC±10%; 220-240 VAC±10%
Power Consumption Power Save	140 W (Mode 1 : <15 W), (Mode 2 (Off) : <3 W)
Power Cord	U.S. version cord (with 3P plug NEMA 5-15P)
Compact Tilt/ Swivel Base	Integrated with monitor
Screen Control	ScreenManager® & ScreenManager Pro One Touch Auto Adjustment Function (Auto-Sizing)
Power Management	VESA DPMS and EIZO MPMS
Operating Conditions Temperature Humidity Altitude	 32 to +95 degrees F. (0 to +35 degrees C.) 30% to 80% Non condensing
Dimensions (W x H x D)	19.4" × 19.1" × 20.5" (494 x 486 x 520 mm)
Weight	66.1 lbs. (30.0 kg)
Regulatory approvals 100-120 VAC Range 220-240 VAC Range	 UL/C-UL, FCC-B, DHHS, TÜV Rheinland/Ergonomics Approved, TCO'99, EPA Energy Star® Program CE, CB, TÜV Rheinland/GS, TÜV Rheinland/Ergonomics Approved, TCO'99, EPA Energy Star® Program
Warranty	

Additional manufacturer-supplied information:

EIZO's new flagship model, the F980, expands the performance capabilities of CRT displays to new levels. This 21 inch shadow mask CRT boasts a sharp dot pitch of 0.23 mm (horizontal pitch: 0.20 mm) and a horizontal scanning range of 30 - 137 Hz to allow a maximum resolution of 2048 x 1536 with a flicker-free refresh rate of 85 Hz. Image performance is unmatched with functions such as Color Correction and video bypass circuitry. CAD/CAM, DTP, and DIP professionals who seek the highest quality display and advanced user friendly features will find the F980 meets their demands.

High Refresh Rates and Large Screen Size - The F980 utilizes a newly developed shadow mask CRT with a super fine horizontal pitch of 0.20 mm (dot pitch of 0.23 mm), and can display high resolutions with extreme clarity. SuperErgoCoat™ reduces external reflection to help eliminate eye fatigue and present a pleasant, clear picture. An active display size of 402 mm (H) × 300 mm (V) provides CAD/CAM, DTP, and DIP professionals with the generous corner to corner large screen they demand.

Maximum Horizontal Scanning Frequency of 137 kHz for High Resolutions - The F980's wide horizontal scanning frequency of 30-137 kHz allows for a recommended resolution of 1600 × 1200 at a maximum refresh rate of 109 Hz. For users who need to maximize the performance capabilities of the display, the monitor can attain a resolution of 2048 × 1536 at a flicker-free refresh rate of 85 Hz

Pixel Dot Clock of 400 MHz - To assure that images are displayed with sharpness and clarity at the maximum resolution of 2048 × 1536 at 85 Hz, the F980 has an extremely high pixel dot clock of 400 MHz. As shown in the illustration below, black text on a white background is displayed in minute detail without blur or distortion.

Pixel Dot Clock Needed for Fine Detail - The following chart shows the pixel dot clock figures necessary to achieve the corresponding resolutions, horizontal scanning ranges, and refresh rates.

Resolution	Horizontal Scanning Range	Refresh Rate	Dot Clock
2048 × 1536	137.020 kHz	85 Hz	388.041 MHz
2048 × 1536	120.225 kHz	75 Hz	340.477 MHz
1920 × 1440	128.520 kHz	85 Hz	341.349 MHz
1600 × 1200	127.100 kHz	100 Hz	280.637 MHz

Automatic Color Correction Function for True Color Reproduction - Color Correction detects and compensates for discrepancies in video signal output levels sent from the graphics card. Therefore, disparities in video signal output level are minimized, and accurate color temperature and brightness are assured. This function also corrects output and unifies color temperature when two computers are connected to the F980, even if the graphics cards and operating systems are different.

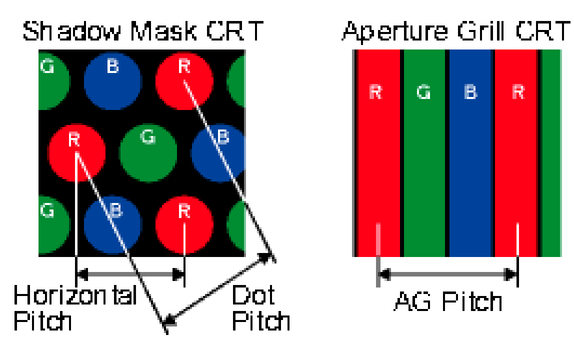
Realistic Picture Display with Video Bias Circuitry - The new video bias circuitry minimizes color changes due to variations in brightness and the variation of the displayed image pattern (i.e. between white pattern image and black pattern image). In addition, minimization of cross modulation improves color reproduction to give graphics and photographs an even greater true-to-life feeling than was possible with previous models.

Digital Convergence Circuitry for Screen Uniformity - EIZO's Digital Convergence circuitry digitally eliminates convergence errors through the adjustment of up to 256 squares over the entire screen for precise images, even in the corners.

Other Advanced Features of the F980

- EIZO's own Digital Signal Processor (DSP) to correct screen distortion and improve resistance against electromagnetic interference from sources such as mobile phones.
- Two signal filters to correct ghosting and moiré.
- Auto-Sizing button located on the front bezel for simple and quick readjustment of the displayed image to the ideal setting.

Retail Price: $1,899.00



I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:

- Quantum Data 8701 400 MHz programmable test pattern signal generator
- Quantum Data 903 250 MHz programmable test pattern signal generator
- Photo Research SpectraScan PR-650 spectroradiometer
- Photo Research SpectraScan PR-704 spectroradiometer
- Minolta LS-100 Photometer
- Minolta CA-100 Colorimeter
- Graseby S370 Illuminance Meter
- Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter) and Spotseeker 4-Axis Positioner

Stereoscopic-mode measurements were made using the following commercially-available stereo products:

- StereoGraphics ZScreen 19-inch LCD shutter with passive polarized eyeglasses.
- StereoGraphics CrystalEyes III IR Eyewear.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic range and Screen Reflectance

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.*

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black dynamic range measured in 1600 x 1200 format is 25.1 dB in a dark room. It decreases to 21.4 dB (the absolute threshold for IEC is 22 dB) in 3 fc diffuse ambient illumination.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

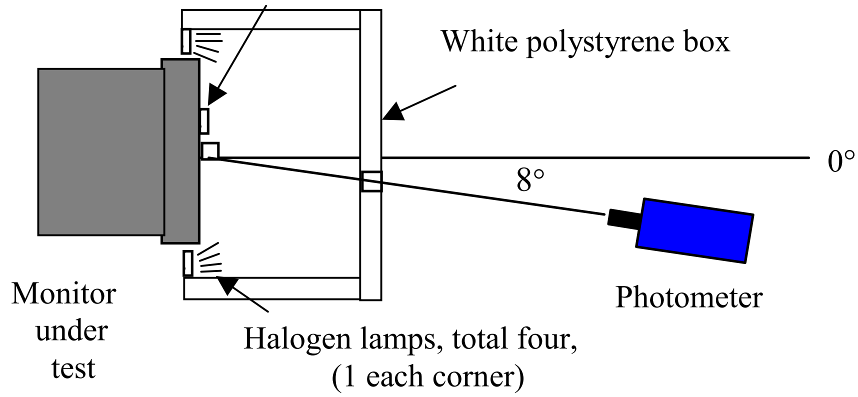
Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of zero and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Data: Define dynamic range by: DR=10log(Lmax/Lmin)



- Top View -

Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	18.96 fc
Reflected Luminance	0.841 fL
Faceplate Reflectance	4.4 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for various levels of diffuse ambient lighting using the measured value for DHR and the darkroom dynamic range measurements. Full screen white-to-black dynamic range decreases from 25.1 dB in a dark room to 22.3 dB (the absolute threshold for IEC) in 2 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.10 fL.

Ambient Illumination	Displayed Addressable Format 1600 x 1200
0 fc (Dark Room)	25.1 dB
1 fc	23.5 dB
2 fc	22.3 dB
3 fc	21.4 dB
4 fc	20.7 dB
5 fc	20.0 dB
6 fc	19.5 dB
7 fc	19.0 dB
8 fc	18.6 dB
9 fc	18.2 dB
10 fc	17.8 dB

II.2. Maximum Luminance (Lmax)

References: *Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.*

The highest luminance for Lmax was 32.4 fL measured at screen center in 1600 x 1200 format.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1600 x 1200	9110K	0.280	0.308	32.4 fL

II.3. Luminance (Lmax) and Color Uniformity

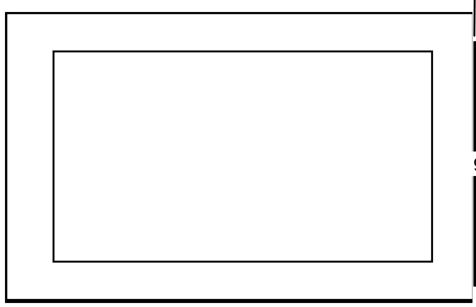
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied by up to 14.1% across the screen. Chromaticity variations were less than 0.003 delta u'v' units.

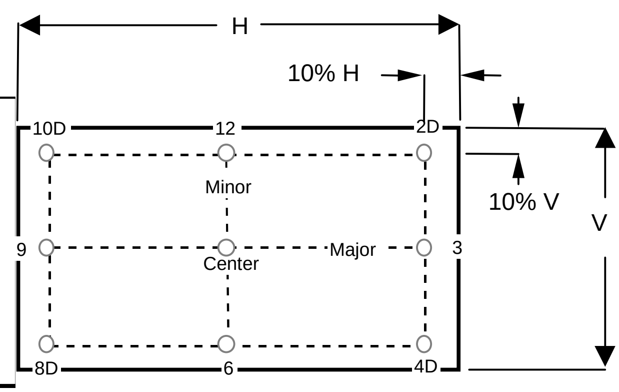
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment:
- Video generator
- Photometer
- Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.



Full Screen Flat Field test pattern.
Figure II.3-1



Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}. Measure the luminance and C.I.E. color coordinates at center screen.

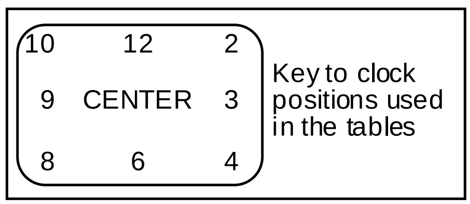
Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of Δu′v′.

Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color
Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1600 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	9110	0.280	0.308	32.4
2	9157	0.279	0.309	31.9
3	8912	0.282	0.309	28.1
4	9097	0.281	0.306	29.0
6	9219	0.280	0.305	30.8
8	9145	0.280	0.307	30.3
9	9204	0.278	0.310	29.7
10	9240	0.278	0.309	30.5
12	9157	0.279	0.309	32.7



1600 x 1200

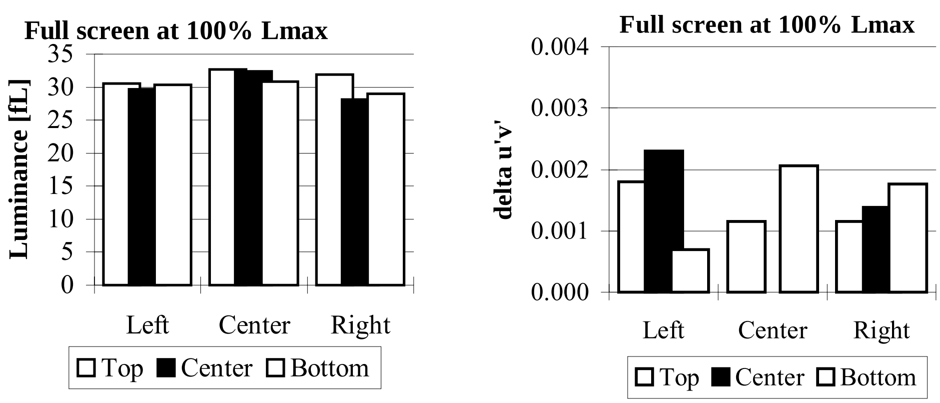


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

Halation was 4.15 % +/- 0.4% on a small black patch surrounded by a large full white area.

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate. The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer. The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment:
- Photometer
- Video generator

Test Pattern:

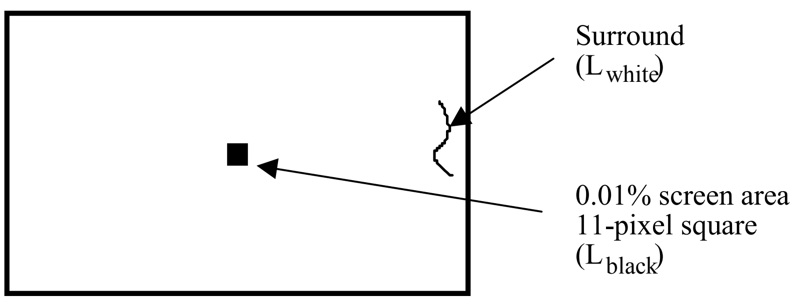


Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.

Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that

CRT beam is just on the verge of being cut off. These measurements should be made with a photometer that is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video-input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation} = L_{black} / (L_{white} - L_{black}) \times 100$$

Where, L_{black}= measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white}= measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max}.

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1600 x 1200 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	0.903 fL ± 4%	0.867 fL to 0.939 fL
Lwhite	21.78 fL ± 4%	20.9 fL to 22.7 fL
Halation	4.15% ± 0.5%	3.83% to 4.49%

II.5. Color Temperature

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

The CCT of the measured white point lies within the boundaries accepted by IEC.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 □u'v' of the corresponding CIE daylight, which is defined as follows: If the measured screen white has a CCT between 6500 and 9300 K, the corresponding daylight has the same CCT as the screen white. If the measured CCT is greater than 9300 K, the corresponding daylight is D93. If the measured CCT is less than 6500 K, the corresponding daylight is D65. The following equations were used to compute □u'v' values listed in table II.5.1:

1. Compute the correlated color temperature (CCT) associated with (x,y) by the VESA/McCamy formula: $CCT = 437 n^3 + 3601 n^2 + 6831 n + 5517$, where $n = (x-0.3320)/(0.1858 - y)$. [This is on p. 227 of the FPDM standard]

2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second edition) to compute the point (xd,yd) associated with CCT.
   - First, define u = 1000/CCT.
   - If CCT < 7000, then $xd = -4.6070 u^3 + 2.9678 u^2 + 0.09911 u +$
   - 0.244063.
   - If CCT > 7000, then $xd = -2.0064 u^3 + 1.9018 u^2 + 0.24748 u +$
   - 0.237040.
   - In either case, $yd = -3.000 xd^2 + 2.870 xd - 0.275$.

5. Convert (x,y) and (xd,yd) to u'v' coordinates:
   - $(u',v') = (4x,9y)/(3 + 12y - 2x)$
   - $(u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)$

6. Evaluate delta-u'v' between (u,v) and (ud,vd):
   - $\text{delta-}u'v' = \text{sqrt}[(u' - u'd)^2 + (v' - v'd)^2]$.

7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise, it passes the test.

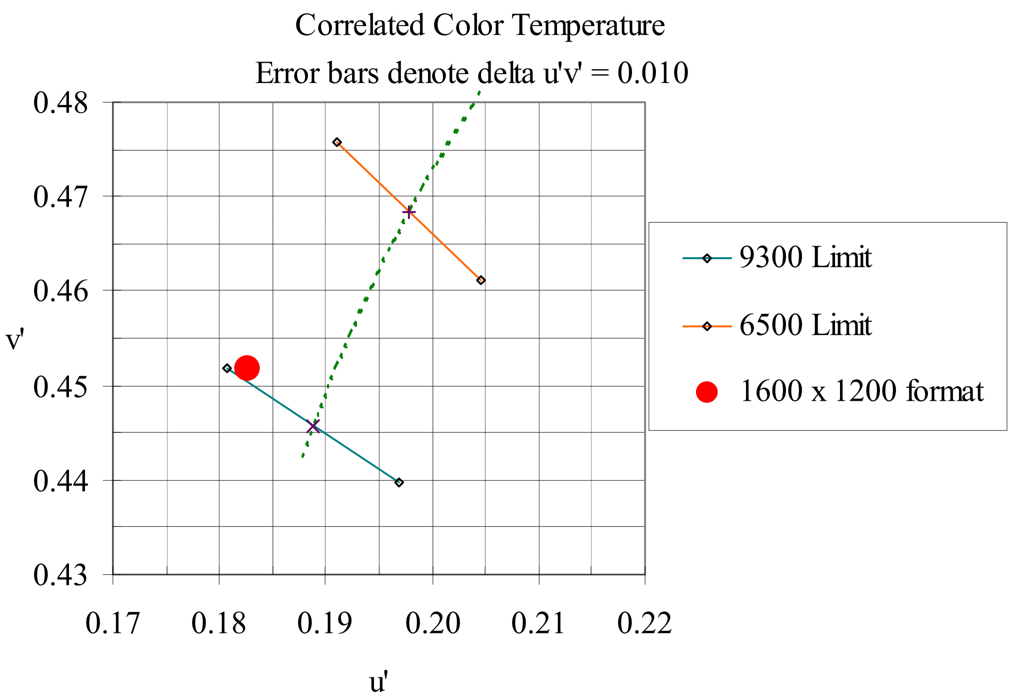


Figure II.5-1 *CCTs of measured white points are within the boundaries required by IEC.*

Table II.5-1 Δu'v' Distances between measured white points and CIE coordinate values from D_{65} to D_{93}.

	1600 x 1200
CIE x	0.280
CIE y	0.308
CIE u'	0.183
CIE v'	0.452
CCT	9110
delta u'v'	0.008

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are n four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM model to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to 0.5* ((0.7 *P)+0.3*n) where P = patch command level, n = number of command levels. The NEMA/DICOM model was used to define discriminable luminance differences in JNDs.

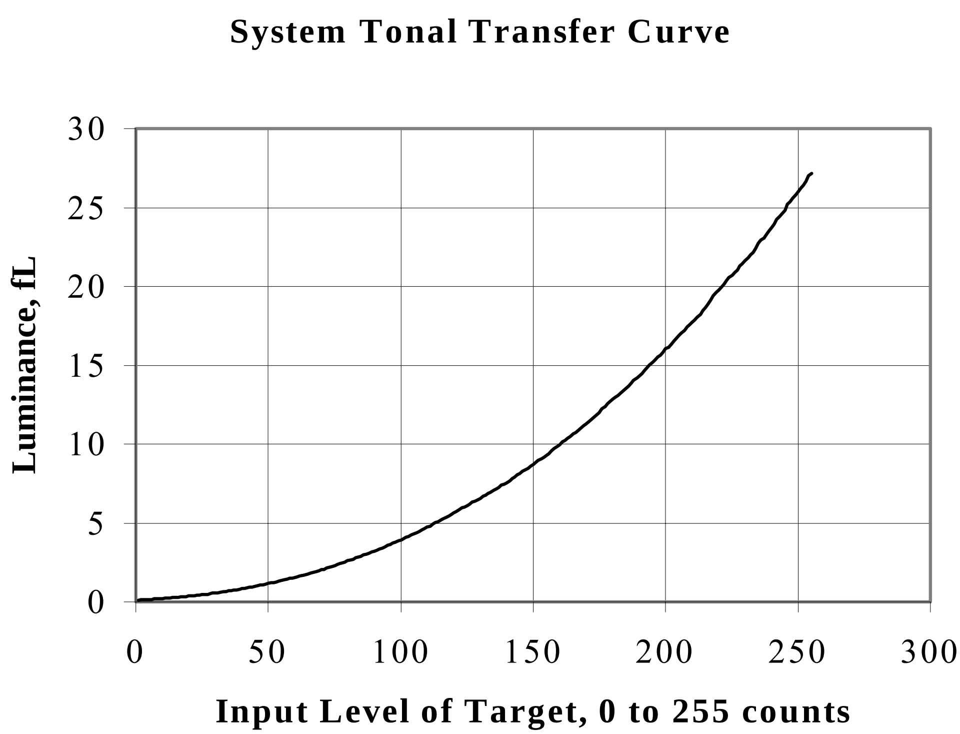


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.109	0.000	0
39	1	0.116	0.007	2
39	2	0.124	0.008	2
39	3	0.133	0.009	2
40	4	0.143	0.010	2
40	5	0.152	0.009	2
41	6	0.162	0.010	2
41	7	0.172	0.010	2
41	8	0.182	0.010	2
42	9	0.193	0.011	2
42	10	0.208	0.015	3
42	11	0.221	0.013	2
43	12	0.235	0.014	2
43	13	0.247	0.012	2
43	14	0.259	0.012	2
44	15	0.273	0.014	2
44	16	0.289	0.016	3
44	17	0.305	0.016	2
45	18	0.320	0.015	2
45	19	0.336	0.016	2
45	20	0.352	0.016	2
46	21	0.370	0.018	2
46	22	0.390	0.020	3
46	23	0.411	0.021	2
47	24	0.428	0.017	2
47	25	0.449	0.021	2
48	26	0.468	0.019	2
48	27	0.486	0.018	2
48	28	0.509	0.023	2
49	29	0.535	0.026	3
49	30	0.560	0.025	2
49	31	0.578	0.018	2
50	32	0.602	0.024	2
50	33	0.629	0.027	3
50	34	0.654	0.025	2
51	35	0.681	0.027	2
51	36	0.703	0.022	2
51	37	0.730	0.027	2
52	38	0.759	0.029	2
52	39	0.789	0.030	2
52	40	0.815	0.026	2
53	41	0.844	0.029	2
53	42	0.876	0.032	3
53	43	0.911	0.035	2
54	44	0.949	0.038	3
54	45	0.982	0.033	2
55	46	1.009	0.027	2
55	47	1.048	0.039	2
55	48	1.078	0.030	2
56	49	1.118	0.040	2
56	50	1.147	0.029	2
56	51	1.196	0.049	3
57	52	1.226	0.030	2
57	53	1.268	0.042	2
57	54	1.308	0.040	2
58	55	1.345	0.037	2
58	56	1.386	0.041	2
58	57	1.428	0.042	2
59	58	1.466	0.038	2
59	59	1.503	0.037	2
59	60	1.547	0.044	2
60	61	1.582	0.035	2
60	62	1.636	0.054	2
60	63	1.688	0.052	3

Back ground	Target	L, fL	Diff, fL	Diff, JND
61	64	1.728	0.040	1
61	65	1.779	0.051	3
62	66	1.821	0.042	1
62	67	1.859	0.038	2
62	68	1.922	0.063	3
63	69	1.976	0.054	2
63	70	2.028	0.052	2
63	71	2.062	0.034	1
64	72	2.124	0.062	3
64	73	2.174	0.050	1
64	74	2.228	0.054	2
65	75	2.282	0.054	2
65	76	2.349	0.067	3
65	77	2.406	0.057	2
66	78	2.458	0.052	2
66	79	2.513	0.055	1
66	80	2.582	0.069	3
67	81	2.648	0.066	2
67	82	2.711	0.063	2
67	83	2.771	0.060	2
68	84	2.821	0.050	1
68	85	2.892	0.071	3
69	86	2.959	0.067	2
69	87	3.009	0.050	1
69	88	3.078	0.069	2
70	89	3.147	0.069	2
70	90	3.216	0.069	2
70	91	3.278	0.062	2
71	92	3.345	0.067	2
71	93	3.415	0.070	1
71	94	3.491	0.076	3
72	95	3.569	0.078	2
72	96	3.631	0.062	1
72	97	3.707	0.076	2
73	98	3.785	0.078	2
73	99	3.853	0.068	2
73	100	3.926	0.073	2
74	101	4.001	0.075	1
74	102	4.079	0.078	2
74	103	4.156	0.077	2
75	104	4.229	0.073	2
75	105	4.312	0.083	2
76	106	4.381	0.069	1
76	107	4.475	0.094	2
76	108	4.545	0.070	2
77	109	4.638	0.093	2
77	110	4.737	0.099	2
77	111	4.794	0.057	1
78	112	4.909	0.115	2
78	113	5.008	0.099	2
78	114	5.087	0.079	2
79	115	5.186	0.099	2
79	116	5.265	0.079	1
79	117	5.347	0.082	2
80	118	5.432	0.085	2
80	119	5.545	0.113	2
80	120	5.635	0.090	1
81	121	5.718	0.083	2
81	122	5.826	0.108	2
81	123	5.939	0.113	2
82	124	6.010	0.071	1
82	125	6.103	0.093	2
83	126	6.208	0.105	1
83	127	6.316	0.108	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts
Target levels 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
83	128	6.389	0.073	1	106	192	14.65	0.17	2
84	129	6.485	0.096	2	106	193	14.82	0.17	1
84	130	6.564	0.079	1	106	194	15.01	0.19	2
84	131	6.687	0.123	2	107	195	15.19	0.18	1
85	132	6.745	0.058	1	107	196	15.36	0.17	1
85	133	6.891	0.146	3	107	197	15.52	0.16	2
85	134	6.948	0.057	0	108	198	15.65	0.13	1
86	135	7.054	0.106	2	108	199	15.83	0.18	1
86	136	7.147	0.093	1	108	200	16.04	0.21	2
86	137	7.256	0.109	2	109	201	16.15	0.11	1
87	138	7.384	0.128	2	109	202	16.33	0.18	1
87	139	7.440	0.056	1	109	203	16.51	0.18	1
87	140	7.542	0.102	1	110	204	16.69	0.18	2
88	141	7.668	0.126	2	110	205	16.87	0.18	1
88	142	7.816	0.148	2	111	206	17.04	0.17	1
88	143	7.889	0.073	1	111	207	17.21	0.17	2
89	144	8.064	0.175	3	111	208	17.44	0.23	1
89	145	8.158	0.094	1	112	209	17.57	0.13	1
90	146	8.266	0.108	1	112	210	17.72	0.15	1
90	147	8.382	0.116	2	112	211	17.86	0.14	1
90	148	8.485	0.103	1	113	212	18.03	0.17	1
91	149	8.607	0.122	2	113	213	18.24	0.21	2
91	150	8.712	0.105	1	113	214	18.46	0.22	1
91	151	8.859	0.147	2	114	215	18.67	0.21	2
92	152	8.957	0.098	2	114	216	18.88	0.21	1
92	153	9.065	0.108	1	114	217	19.13	0.25	2
92	154	9.162	0.097	1	115	218	19.41	0.28	2
93	155	9.319	0.157	2	115	219	19.61	0.20	1
93	156	9.413	0.094	1	115	220	19.76	0.15	1
93	157	9.584	0.171	2	116	221	19.97	0.21	1
94	158	9.728	0.144	2	116	222	20.15	0.18	2
94	159	9.862	0.134	2	116	223	20.38	0.23	1
94	160	9.953	0.091	1	117	224	20.56	0.18	1
95	161	10.120	0.167	1	117	225	20.72	0.16	1
95	162	10.250	0.130	2	118	226	20.88	0.16	1
95	163	10.370	0.120	1	118	227	21.04	0.16	1
96	164	10.480	0.110	2	118	228	21.28	0.24	2
96	165	10.640	0.160	1	119	229	21.43	0.15	1
97	166	10.760	0.120	2	119	230	21.61	0.18	1
97	167	10.890	0.130	1	119	231	21.80	0.19	1
97	168	11.020	0.130	1	120	232	21.99	0.19	1
98	169	11.140	0.120	2	120	233	22.12	0.13	1
98	170	11.270	0.130	1	120	234	22.43	0.31	1
98	171	11.420	0.150	2	121	235	22.76	0.33	2
99	172	11.580	0.160	1	121	236	22.92	0.16	1
99	173	11.710	0.130	2	121	237	23.07	0.15	1
99	174	11.840	0.130	1	122	238	23.28	0.21	1
100	175	12.020	0.180	2	122	239	23.52	0.24	2
100	176	12.220	0.200	2	122	240	23.74	0.22	1
100	177	12.380	0.160	1	123	241	23.97	0.23	1
101	178	12.580	0.200	2	123	242	24.24	0.27	2
101	179	12.710	0.130	1	123	243	24.45	0.21	1
101	180	12.860	0.150	2	124	244	24.64	0.19	1
102	181	12.980	0.120	1	124	245	24.86	0.22	1
102	182	13.090	0.110	1	125	246	25.19	0.33	2
102	183	13.260	0.170	1	125	247	25.35	0.16	1
103	184	13.380	0.120	2	125	248	25.57	0.22	1
103	185	13.530	0.150	1	126	249	25.81	0.24	1
104	186	13.690	0.160	1	126	250	25.98	0.17	1
104	187	13.880	0.190	2	126	251	26.23	0.25	1
104	188	14.040	0.160	1	127	252	26.44	0.21	1
105	189	14.170	0.130	2	127	253	26.67	0.23	1
105	190	14.310	0.140	1	127	254	27.02	0.35	2
105	191	14.480	0.170	1	128	255	27.18	0.16	1

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

No video artifacts were observed.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern

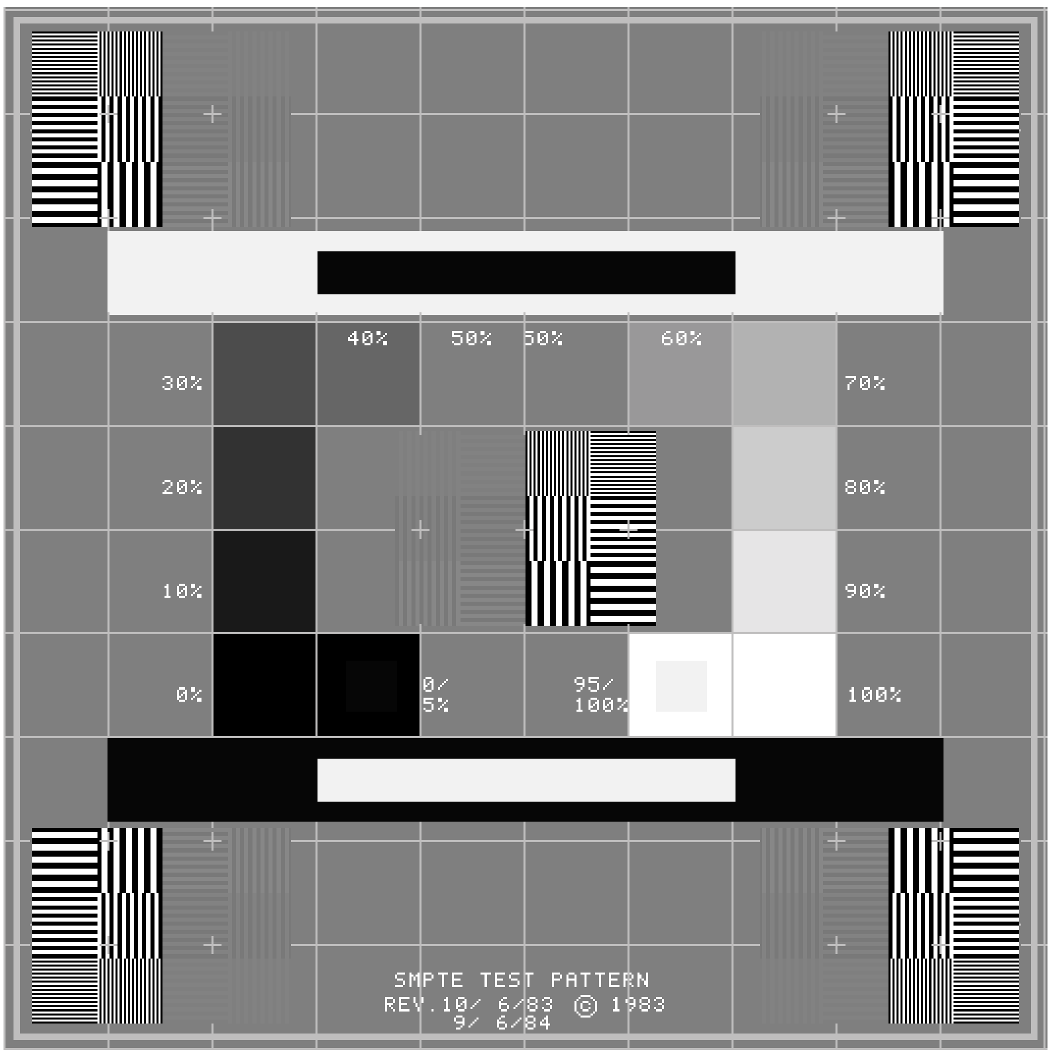


Figure II.8-1. SMPTE Test Pattern.

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo." None of these artifacts was observed in the EIZO F980 monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the following tested formats (HxV): 1600 x 1200 x 85 Hz, and 1024 x 1024 x 120 Hz.

Objective: Define the number of addressable pixels in the horizontal and vertical dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
Test pattern with pixels lit on first and last addressable rows and columns and on two diagonal lines beginning at upper left and lower right; H & V grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 75 Hz minimum for monoscopic mode and 100 Hz minimum for stereoscopic mode, where possible. All perimeter lines were confirmed to be visible, with no irregular jaggies on diagonals and, for monochrome monitors, no strongly visible moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If test fails, addressability unknown.

Table II.9-1 Addressabilities Tested

Monoscopic Mode	Stereo Mode
1600 x 1200	1024 x 1024

II.10. Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is within 1.2%.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

	Monoscopic Mode
Addressability (H x V)	**1600 x 1200**
H x V Image Size (inches) H x V Pixel Spacing (mils) H x V Pixel Aspect Ratio	15.436 x 11.439 9.65 x 9.53 mils H = V + 1.2%

II.11. Screen Size (Viewable Active Image)

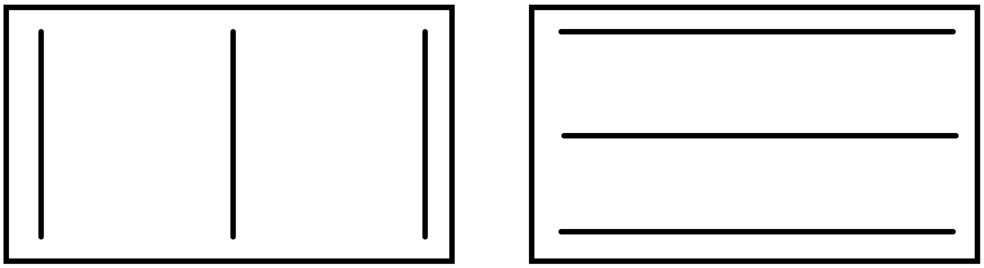
Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size for 1600 x 1200 format was 19.2 inches in diagonal.

Objective: Measure beam position on the CRT display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square-root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Modes
Addressability (H x V)	1600 x 1200
H x V Image Size (inches) Diagonal Image Size (inches)	15.436 x 11.439 19.212

II.12. Contrast Modulation

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax exceeded Cm = 37% in Zone A of diameter 7.6 inches, and35% for Zone A diameter of 9.48 inches (40% of image area. Cm exceeded 27% in Zone B.

Objective: Quantify contrast modulation as a function of screen position.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Photometer with linearized response

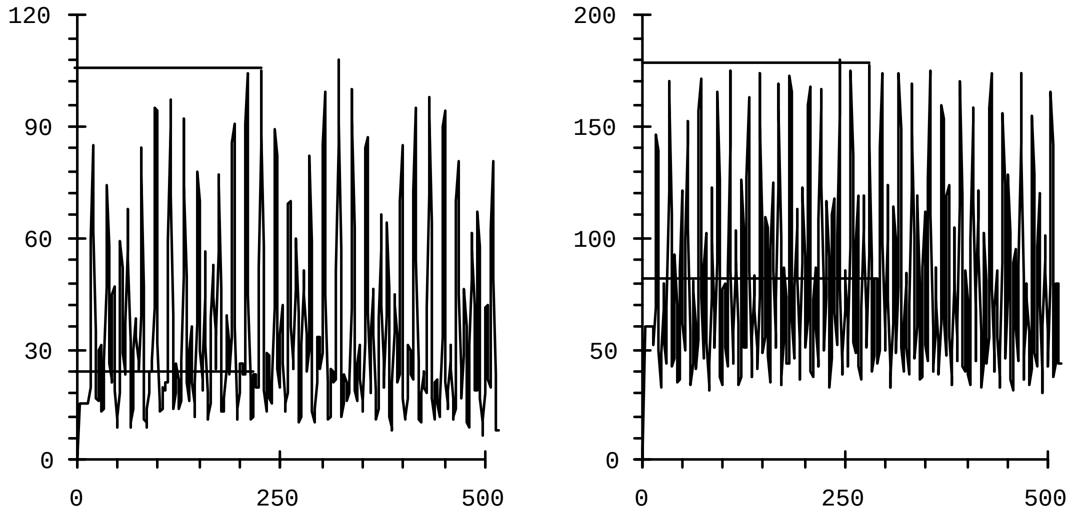
Procedure: The maximum video modulation frequency for each format (1280 x 1024, 1620 x 1024, 1920 x 1200) was examined using horizontal and vertical grille test patterns consisting of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was measured in both horizontal and vertical directions at screen center and at eight peripheral screen positions. The measurements should be along the horizontal and vertical axes and along the diagonal from these axes. Use edge measurements no more than 10% of screen size in from border of active screen. The input signal level was set so that 1-line-on/1-line-off horizontal grille patterns produced a screen area-luminance of 25% of maximum level, Lmax.

Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). Determine Cm at eight points on circumference of circle by interpolating between center and display edge measurements to define Cm for Zone A. If measurements exceed the threshold, do not make any more measurements. If one or more measurements fail the threshold, make eight additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation is equal to or greater than 37% in Zone A, and is equal to or greater than 27% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadow mask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.



Monitor A
0.28mm dot pitch

Monitor B
0.26mm dot pitch

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for monitors exhibiting moiré due to aliasing.*

Table II.12-1. Contrast Modulation

Corrected for lens flare and Zone Interpolation

Moiré Cancellation OFF

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches viewing distance

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	62%	28%			55%	47%			58%	27%
			69%	37%	62%	46%	67%	37%		
Major	92%	35%	83%	39%	74%	43%	80%	40%	86%	36%
			77%	37%	74%	37%	78%	40%		
Bottom	82%	27%			74%	34%			84%	35%

Zone A = 9.48-inch diameter circle for 40% area

	Left				Minor				Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	62%	28%			55%	47%			58%	27%
			68%	36%	59%	46%	66%	35%		
Major	92%	35%	85%	38%	74%	43%	81%	39%	86%	36%
			78%	35%	74%	35%	79%	39%		
Bottom	82%	27%			74%	34%			84%	35%

II.13. Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 104 ppi as tested for the 1600 x 1200-line addressable format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	1600 x 1200
H x V Image Size, Inches H x V Pixel Density, ppi	15.436 x 11.439 104 x 105 ppi

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

Phosphor-to-pixel spacing ratio is 0.82 at screen center for the 1600 x 1200 format. Moiré compensation circuitry was not evaluated.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

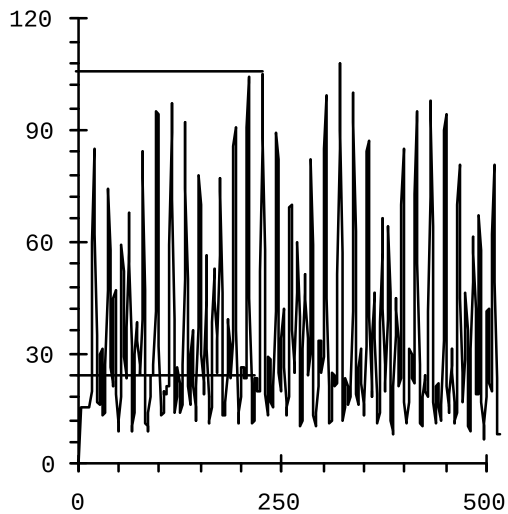
Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

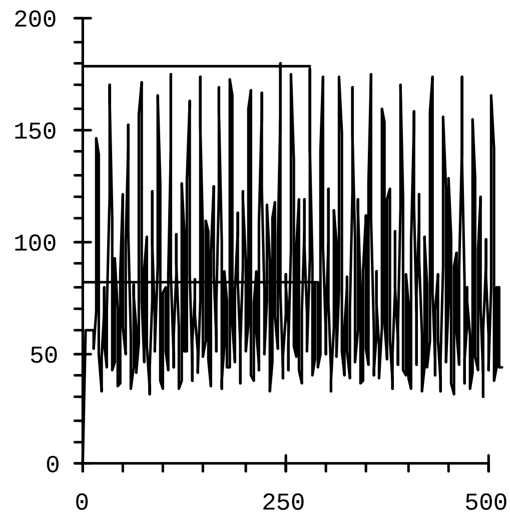
Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1600 x 1200
Phosphor Dot Pitch	0.23 mm, diagonal 0.20 mm, horizontal
Pixel Spacing	9.65 mils, horizontal 0.245 mm, horizontal
Phosphor-to-Pixel-Spacing	0.82

Discussion: Moiré occurs when the phosphor pitch is too large in comparison to the pixel size. Studies have shown that a phosphor pitch of about 0.6 pixels or less is required for adequate visibility of image information without interference from the phosphor structure.



Monitor A
0.28mm dot pitch



Monitor B
0.26mm dot pitch

Figure II.14-1. *Contrast modulation for sample luminance profiles (1pixel at level 50, 1 pixel at level 0) for monitors exhibiting moiré due to aliasing.*

In Figure II.14-1, Monitor A phosphor pitch is 0.90 pixels as compared with 0.84 pixels in Monitor B. Moiré is more visible in Monitor A, appearing as long stripes where contrast modulation has been degraded. In Monitor B, moiré is less visible, appearing as "fish-scales" where contrast modulation has been reduced. Although the Monitor A exhibits a greater loss of contrast modulation from the presence of moiré on 1-on/1-off vertical grille patterns, there is little or no visual impact when aerial photographic images are displayed. NIDL experts in human vision and psychophysics were unable to discern presence of moiré on either monitor when grayscale imagery was displayed.

II.15. Straightness

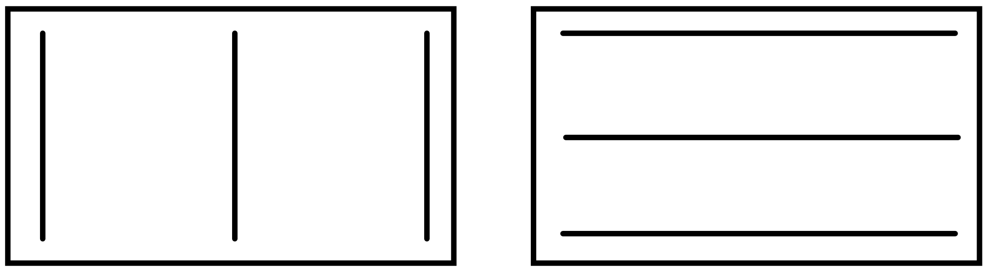
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Waviness, a measure of straightness, did not exceed 0.16% of the image width or height.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.15-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at 100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



1-pixel-wide lines displayed at 100% L_{max}

Figure II.15-1 Three-line grille test patterns.

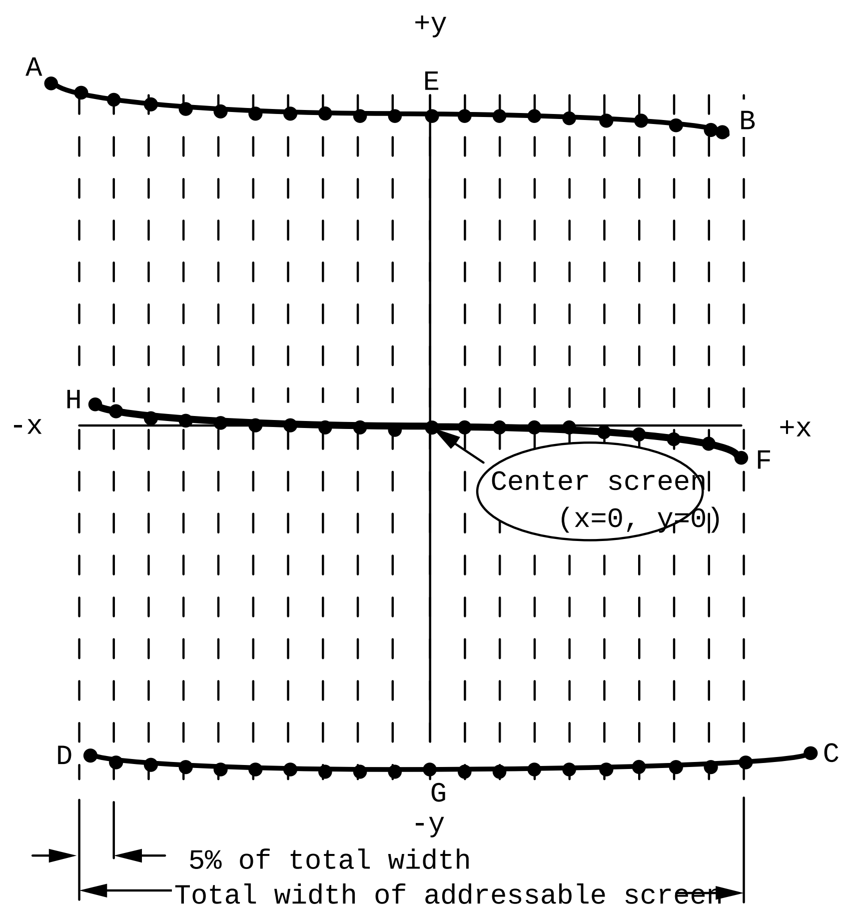


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

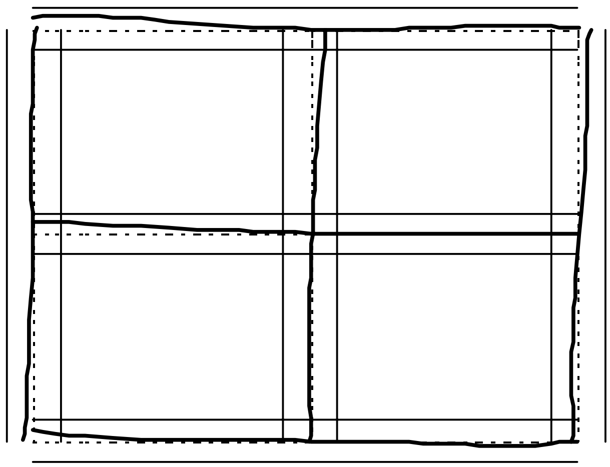
Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness

Tabulated x,y positions at 5% addressable screen increments along nominally straight lines.

Top		**Bottom**		**Major**		**Minor**		**Left Side**		**Right Side**	
x	y	x	y	x	y	x	y	x	y	x	y
-7830	5718	-7866	-5720	-7838	35	36	5683	-7830	5718	7623	5688
-7200	5724	-7200	-5730	-7200	33	34	5400	-7832	5400	7616	5400
-6400	5724	-6400	-5737	-6400	28	28	4800	-7836	4800	7615	4800
-5600	5720	-5600	-5742	-5600	25	23	4200	-7838	4200	7615	4200
-4800	5715	-4800	-5744	-4800	21	18	3600	-7839	3600	7614	3600
-4000	5709	-4000	-5744	-4000	18	12	3000	-7844	3000	7613	3000
-3200	5701	-3200	-5745	-3200	13	9	2400	-7844	2400	7611	2400
-2400	5696	-2400	-5745	-2400	10	6	1800	-7844	1800	7607	1800
-1600	5691	-1600	-5746	-1600	7	3	1200	-7842	1200	7601	1200
-800	5688	-800	-5748	-800	4	1	600	-7838	600	7596	600
0	5686	0	-5749	0	0	-2	0	-7837	0	7591	0
800	5685	800	-5750	800	0	-6	-600	-7837	-600	7586	-600
1600	5685	1600	-5752	1600	0	-9	-1200	-7839	-1200	7582	-1200
2400	5686	2400	-5753	2400	0	-10	-1800	-7844	-1800	7578	-1800
3200	5688	3200	-5756	3200	0	-11	-2400	-7848	-2400	7576	-2400
4000	5692	4000	-5758	4000	-1	-12	-3000	-7852	-3000	7572	-3000
4800	5695	4800	-5761	4800	-1	-12	-3600	-7852	-3600	7571	-3600
5600	5696	5600	-5762	5600	-2	-11	-4200	-7853	-4200	7571	-4200
6400	5696	6400	-5761	6400	-2	-10	-4800	-7858	-4800	7572	-4800
7200	5691	7200	-5754	7200	-2	-8	-5400	-7860	-5400	7574	-5400
7614	5688	7570	-5749	7589	-2	-10	-5752	-7866	-5723	7570	-5752



1600 x 1200

Figure II.15-3 Waviness of EIZO F980 color monitor in 1600 x 1200 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

Vertical refresh rate for 1600 x 1200 format was set to 85 Hz. Vertical refresh rate for the 1024 x 1024 stereo format was 120 Hz.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	1600 x 1200	1024 x 1024
Vertical Scan	85.0 Hz	120 Hz
Horizontal Scan	106.250 kHz	127.100 kHz

II.17. Extinction Ratio (Zscreen, CrystalEyes)

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.17, p10.

Stereo extinction ratio averaged 12.6 to 1 (13.2 left, 12.1 right) at screen center using StereoGraphics Z-Screen 19-inch LCD active shutter and passive polarized glasses. Luminance of white varied by up to 12.7% across the screen. Chromaticity variations of white were less than 0.008 delta u'v' units. Stereo extinction ratio averaged 14.3 to 1 (14.2 left, 14.4 right) at screen center using StereoGraphics CrystalEyes LCD shutter glasses.

Objective: Measure stereo extinction ratio.

Equipment: Two “stereo” pairs with full addressability. One pair has left center at command level of 255 (or Cmax) and right center at 0. The other pair has right center at command level of 255 (or Cmax) and left center at 0.

Stereoscopic-mode measurements were made using a commercially-available StereoGraphics Z-Screen 19-inch LCD active shutter with passive polarized eyeglasses. Stereoscopic-mode measurements were also made using StereoGraphics CrystalEyes LCD active shutter eyeglasses.

Procedure: Calibrate monitor to 0.1 fL Lmin and 35 fL Lmax (no ambient). Measure ratio of Lmax to Lmin on both left and right side images through the stereo system.

Data: Extinction ratio (left) = L (left,on, white/black)/left,off, black/white)

L(left,on, white/black) ~ trans(left,on)*trans(stereo)*L(max)*Duty(left)
+ trans(left,off)*trans (stereo)*L(min)*Duty (right)
Use left,off/right,on to perform this measurement

Extinction ratio (right) = L (right,on,white/black)/right,off, black/white)

L(right,on, white/black) ~
trans(right,on)*trans(stereo)*L(max)*Duty(right)
+ trans(right,off)*trans (stereo)*L(min)*Duty (left)
Use left,on/right,off to perform this measurement

Stereo extinction ratio is average of left and right ratios defined above.

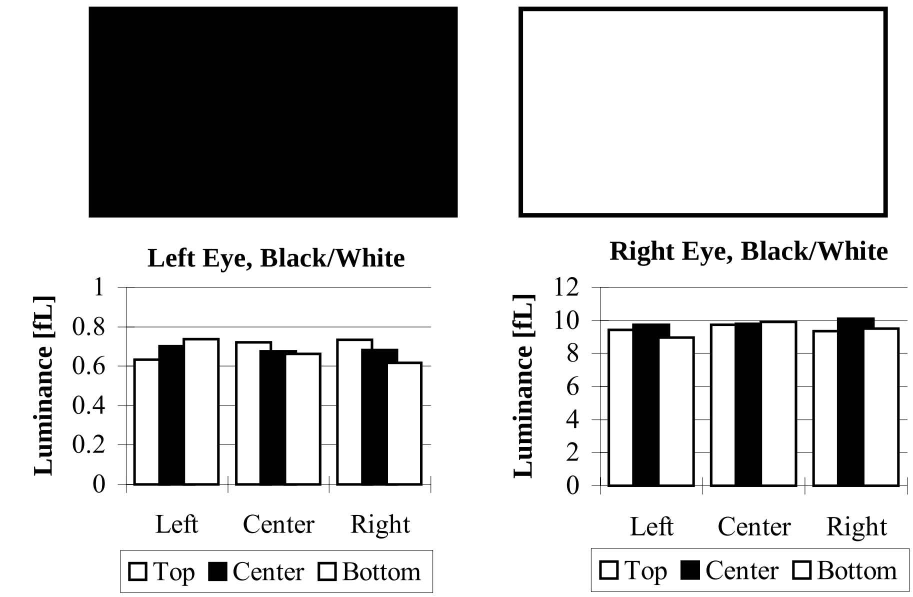


Fig.II.17-1. Spatial Uniformity of luminance in stereo mode when displaying black to the left eye while displaying white to the right eye.

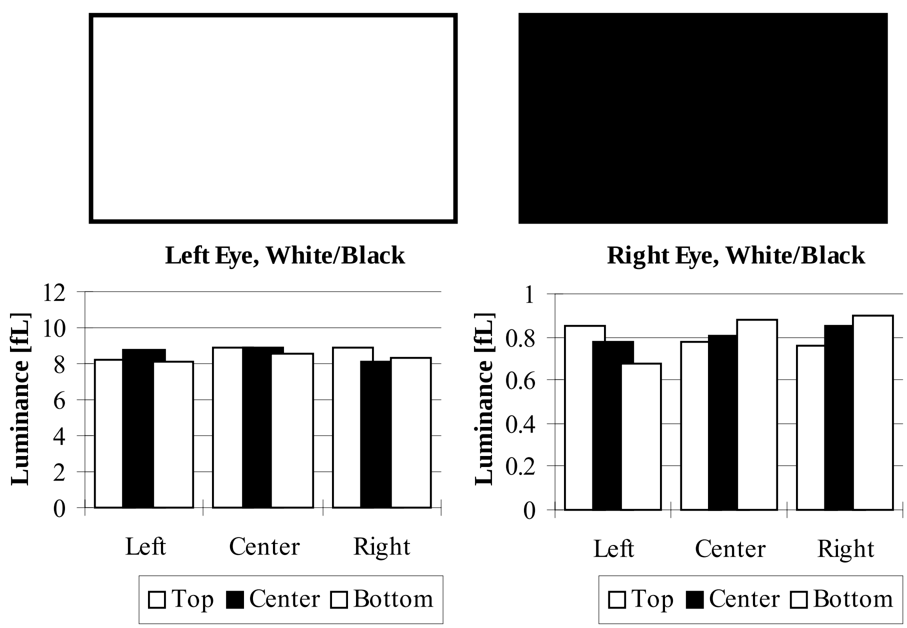


Fig.II.17-2. Spatial Uniformity of luminance in stereo mode when displaying white to the left eye while displaying black to the right eye.

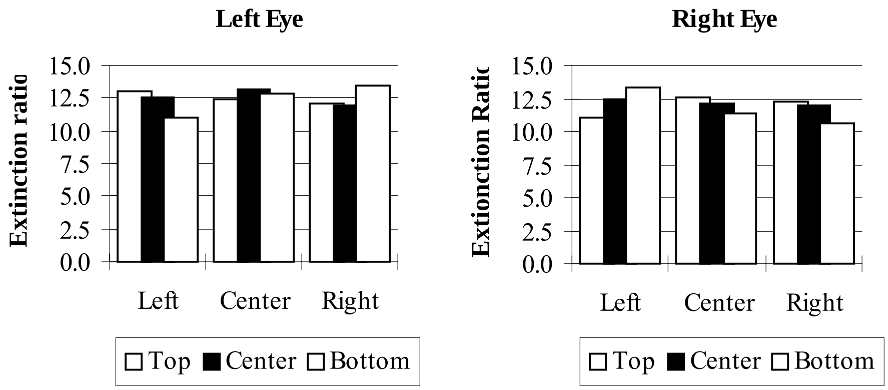


Fig.II.17-3. Spatial Uniformity of extinction ratio in stereo mode.

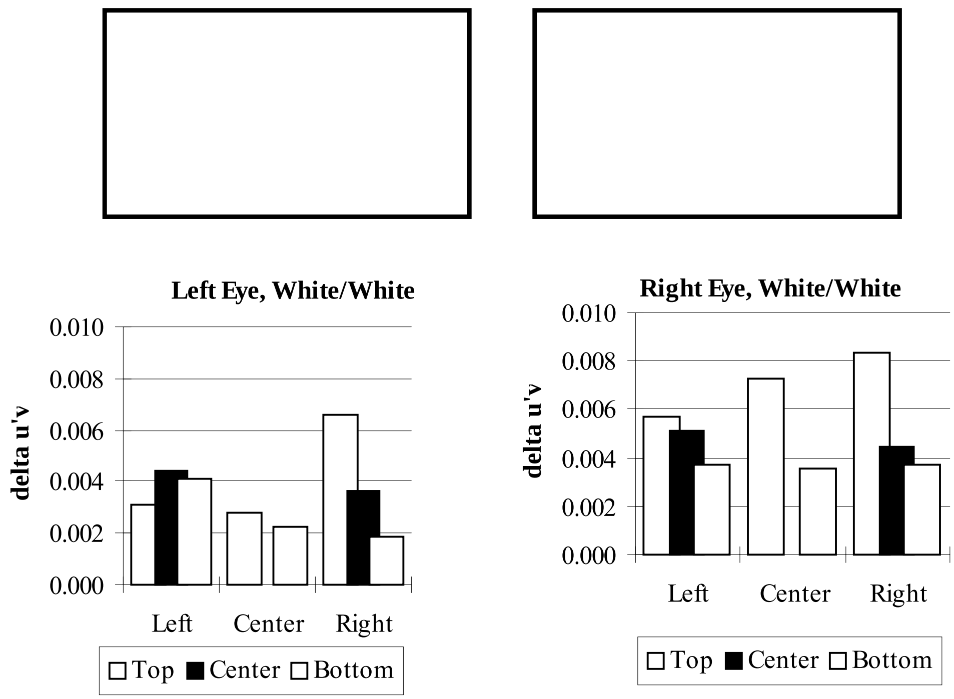


Fig.II.17-4 Spatial uniformity of chromaticity of white in stereo mode.

II.18. Linearity

Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 1.0% of full screen for 1600 x 1200 x 72 Hz format. The auto-setup feature performed less well for the 1600 x 1200 x 85 Hz format, resulting in linearity errors up to 1.2 %.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.

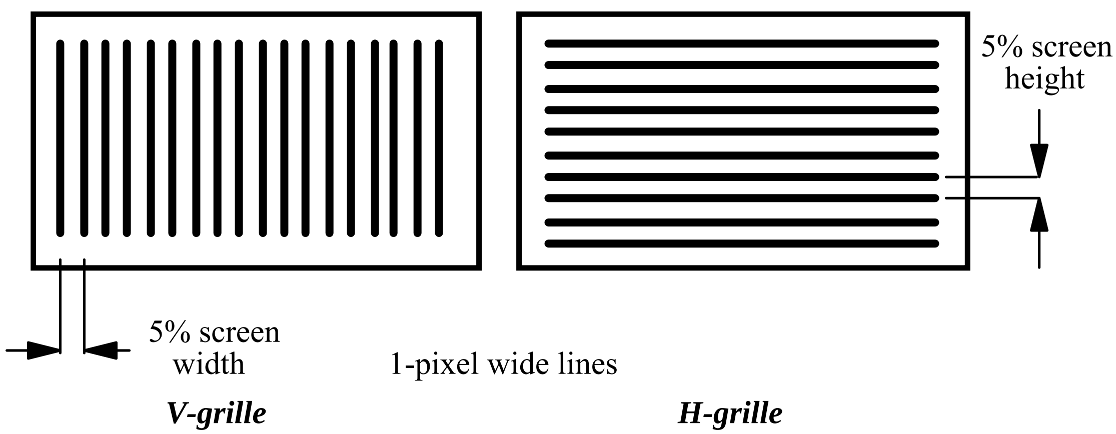


Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

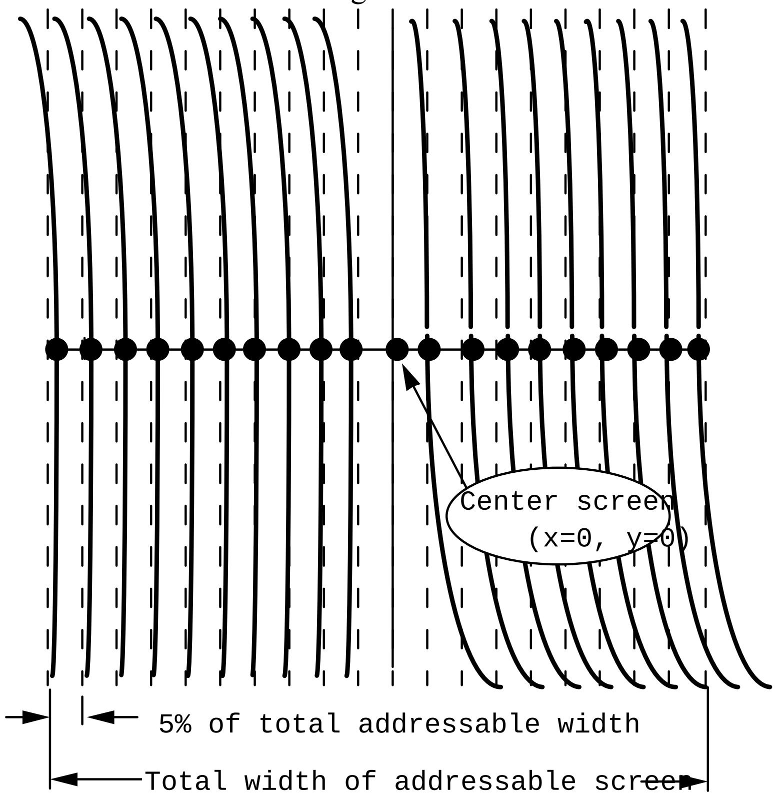


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3 through II.18-6.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1600 x 1200 x 72 Hz	1.01%	0.89%	0.52%	0.23%
1600 x 1200 x 85 Hz	1.20%	0.52%	0.46%	0.08%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

1600 x 1200 x 72 Hz

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-7933	7636	5691	-5724
-7149	6930	5136	-5169
-6351	6187	4573	-4598
-5550	5429	4005	-4025
-4746	4660	3433	-3448
-3944	3885	2861	-2872
-3144	3107	2289	-2297
-2348	2328	1719	-1724
-1559	1552	1148	-1149
-778	777	575	-575
0	0	0	0

1600 x 1200 x 85 Hz

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-7800	7534	5602	-5654
-7019	6822	5051	-5096
-6230	6088	4498	-4533
-5437	5333	3939	-3965
-4644	4573	3376	-3397
-3858	3808	2812	-2829
-3075	3045	2249	-2263
-2299	2280	1689	-1698
-1529	1519	1128	-1131
-762	761	564	-567
0	0	0	0

1600 x 1200 x 72 Hz

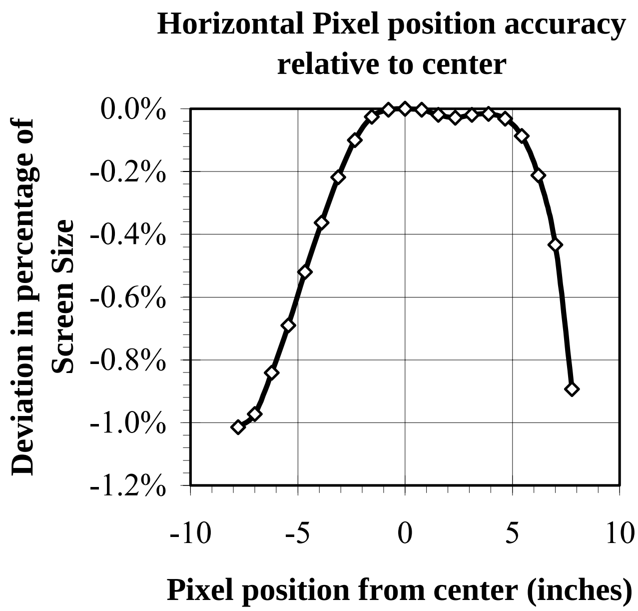


Fig. II.18-3 Horizontal linearity characteristic for 1600 x 1200 x 72 Hz.

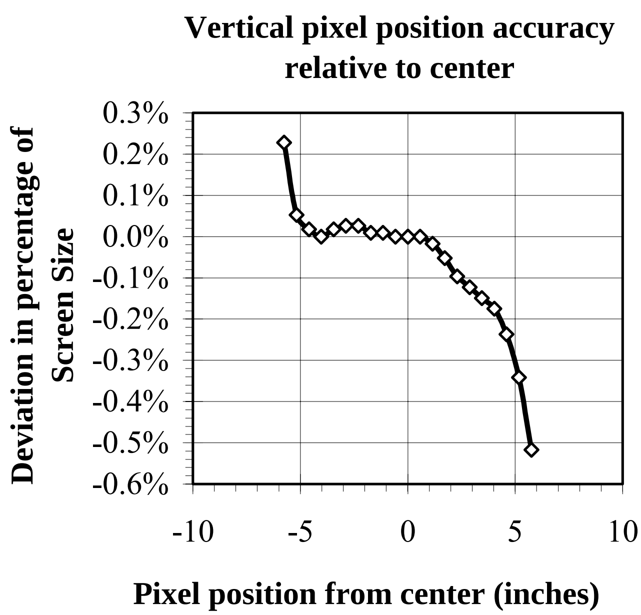


Fig. II.18-4 Vertical linearity characteristic for 1600 x 1200 x 72 Hz.

1600 x 1200 x 85 Hz

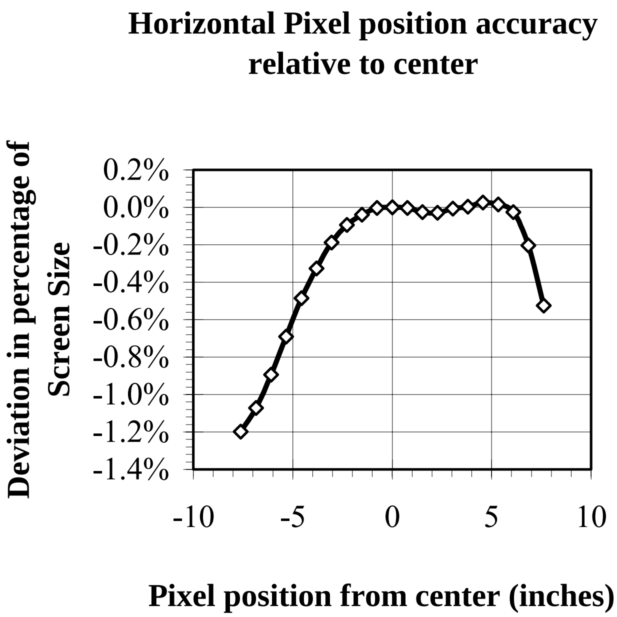


Fig. II.18-5 Horizontal linearity characteristic for 1600 x 1200 x 85 Hz.

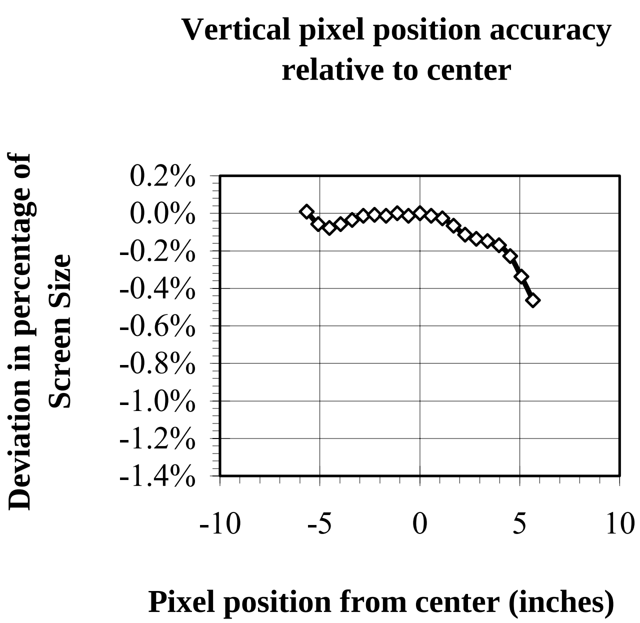


Fig. II.18-6 Vertical linearity characteristic for 1600 x 1200 x 85 Hz

II.19. Jitter/Swim/Drift

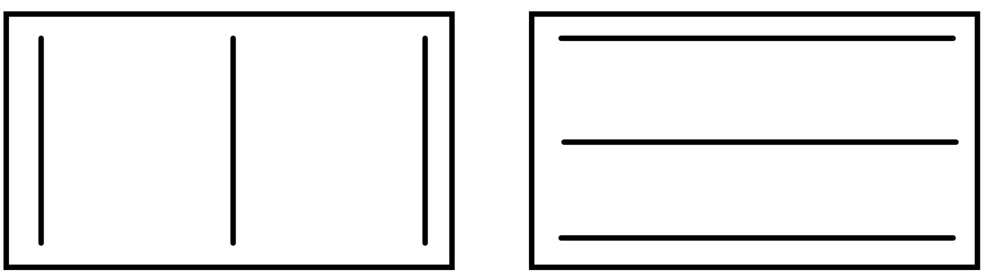
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift was 0.95 mils and 1.99 mils, respectively.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depends upon the amplitude and frequency of the motions, which can be caused by imprecise control electronics or external magnetic fields.

Equipment:
- Video generator
- Spatially calibrated CCD or photodiode array optic module
- Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).



V-grille for measuring horizontal motion H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

Moiré compensation OFF

1600 x 1200 x 85hz

		H-lines	V-lines	
10D corner	Max Motions			
	Jitter	1.11	1.11	
	Swim	2.16	1.27	
	Drift	2.35	1.25	
Black Tape	Max Motions			
	Jitter	0.213	0.156	
	Swim	0.241	0.182	
	Drift	0.356	0.217	
Less Tape Motion				maximums
	Jitter	0.90	0.95	0.95
	Swim	1.92	1.09	1.92
	Drift	1.99	1.03	1.99

II.20 Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

A 42 minute warm-up was necessary for luminance stability of Lmin = 0.10 fL + 10%.

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the data for 1600 x 1200 format in graphical form. The luminance remains very stable after 21 minutes.

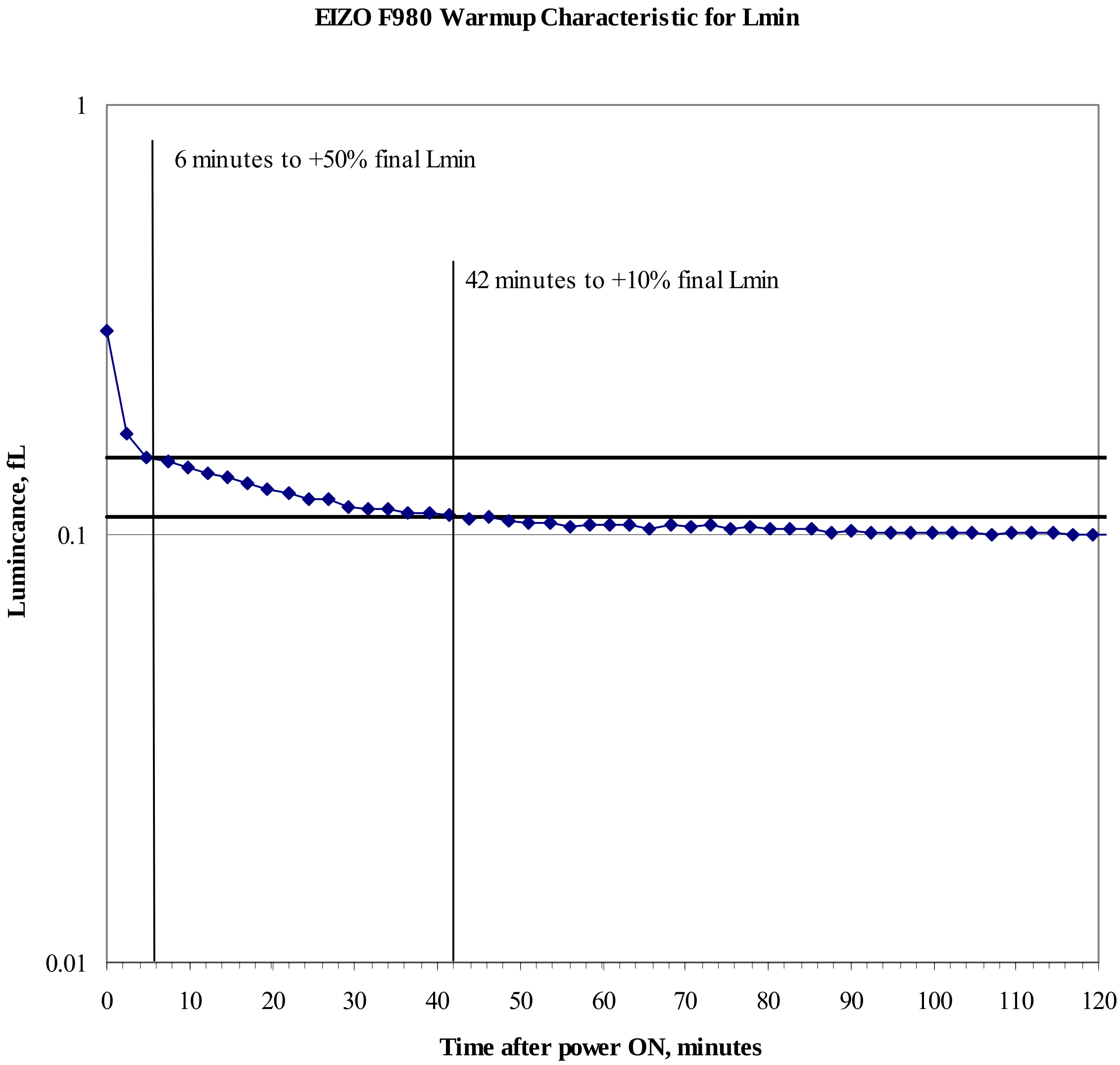


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).